

## INTER-DSP SIGNALING IN A MULTIPLE DSP ENVIRONMENT

### FIELD OF THE INVENTION

The present invention relates generally to digital signal processors (DSPs) and, more particularly, to interrupt signaling between one DSP and other DSPs.

### BACKGROUND OF THE INVENTION

Advances in very large scale integration have contributed to the current digital signal processors (DSPs). These processors are special purpose microprocessors characterized by architectures and instructions suitable for digital signal processing applications. DSPs are utilized in a number of applications from communications and controls to speech and image processing. Special purpose DSPs, designed for a specific signal processing application, such as for fast fourier transform (FFT) have also emerged.

One such DSP, for example the TMS320C30, supports fixed- and floating-point operations. Features of this processor include 32 bit by 32 bit floating-point multiply operations in one instruction cycle time of 60 nsec. Since a number of instructions, such as load and store, multiply and add, can be performed in parallel in one cycle time, the TMS320C30 can execute a pair of instructions in 30 nsec, allowing for 33.3 MIPS. The TMS320C30 has 2K words of on-chip memory and 16 million words of addressable

memory spaces for program, data and input/output. Specialized instructions are available to make common DSP algorithms, such as filtering and spectral analysis, execute fast and efficiently. Like other microprocessors, the DSP may take advantage of higher level languages, such as C and ADA.

5 In a system having multiple independent DSPs, it is often  
necessary to synchronize the bit streams running from one DSP to another  
DSP, and for one DSP to inform or signal another DSP that a specific event  
has occurred. For example, each DSP may be processing its own  
independent task, or processing a subset of a task shared by multiple DSPs.  
10 When a DSP completes processing a first subset of the task, the DSP signals  
the other DSP that the first subset has been completed. The other DSP may  
then perform a second subset of the task. The processors may also exchange  
data and status information, so that order-dependent processing may proceed  
correctly.

15 FIG. 1 illustrates a conventional approach of signaling from one  
DSP to another DSP. As shown, processing system 10 includes DSPØ,  
designated as 12, and DSP1, designated as 14. Dedicated lines are connected  
between DSPØ and DSP1 for providing the signaling function. For example,  
output 1 terminal of DSPØ provides signal 1 to interrupt 1 terminal of DSP1.  
20 By using signal 1, DSPØ informs DSP1 that a specific event has occurred.  
Signal 1 appears as an interrupt signal to DSP1. FIG. 1 also shows signal 2  
placed on another dedicated line between DSPØ and DSP1 for providing a  
second interrupt to DSP1.

Only a limited number of output terminals in a DSP are available for signaling another DSP. This is a disadvantage as additional signaling may be needed to signal other DSPs in a system. A need exists, therefore, to provide a means for signaling a processor from another processor without depending on the availability of output terminals. The output terminals may then be used for other purposes.

### SUMMARY OF THE INVENTION

To meet this and other needs, and in view of its purposes, the present invention provides a method for synchronizing a first processor with a second processor. The method includes storing in a register parallel bits of data from the first processor, wherein at least one bit of data is a logic ONE. An output signal is formed from the one bit of data in the register. The output signal is sent as an interrupt signal to an interrupt terminal of the second processor for synchronizing the first processor with the second processor. The method may be used with a memory mapped register or an off-core register. The first and second processor may be DSP processors or any other type of processors.

It is understood that the foregoing general description and the following detailed description are exemplary, but are not restrictive, of the invention.

### BRIEF DESCRIPTION OF THE DRAWING

The invention is best understood from the following detailed description when read in connection with the accompanying drawing. Included in the drawing are the following figures:

5           FIG. 1 is a block diagram illustrating a conventional system of signaling from one DSP to another DSP;

FIG. 2 is a block diagram illustrating an exemplary embodiment of an inter-DSP signaling system in accordance with the present invention;

10           FIG. 3 is a block diagram illustrating another exemplary embodiment of an inter-DSP signaling system in accordance with the present invention;

FIG. 4 is a block diagram illustrating a bi-directional inter-DSP signaling system between multiple DSPs in accordance with the present invention;

15           FIG. 5 is a block diagram illustrating an exemplary embodiment of inter-DSP signaling using an off-core register implementation in accordance with the present invention;

FIG. 6 is a block diagram showing logic circuitry for converting the off-core register implementation of FIG. 5 to a memory-mapped register implementation in accordance with the present invention; and  
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FIGS. 7(a)-7(i) are timing diagrams showing the relationship of signals as they appear at various points in the exemplary embodiment of FIG. 5.

### DETAILED DESCRIPTION OF THE INVENTION

5 The present invention relates to communications between DSP cores that exist on the same physical chip and implemented as blocks on the chip, or as separate standalone devices implemented as discrete components on a board that utilizes discrete DSP chips. The present invention, although described for DSP applications, also relates to any other type of processor,  
10 such as a general purpose microprocessor, or a microcontroller, for example.

FIG. 2 is a block diagram of inter-DSP signaling system 20 including DSP0 and DSP1, respectively designated as 22 and 24. Interposed between the two DSPs is signal unit 23. As will be explained in detail, signal unit 23 includes a multi-bit register, external to the DSP, that is mapped into  
15 the DSP0's memory space. Signal unit 23 also includes an edge detector to determine when a logic ONE is set in each bit of the register. Depending on which bit is set in the register, signal unit 23 generates a corresponding output signal from the set of signals (for example, signal 1 - signal 8 shown in FIG. 2). One or more of the output signals generated by signal unit 23 is  
20 provided to the interrupt terminals (for example, int<sub>1</sub>-int<sub>8</sub> shown in FIG. 2) of DSP1. The output signals may be routed to maskable interrupt input terminals, non-maskable interrupt input terminals, or both types of interrupt terminals.

By writing a logic ONE to a predetermined address of the signal unit, DSPØ may synchronize with DSP1 by generating a maskable or non-maskable interrupt in DSP1. This method may be repeated between any pair of DSPs, permitting any DSP to signal any other DSP in the system. In addition, the output signals may be routed to multiple DSPs, as shown in FIG. 2. Signals 1-8 are shown routed to DSP1; another output signal (not labeled) may be routed to another DSP (not shown). Although a single output signal is shown being routed to other DSPs, there may be another set of eight output signals being routed to the other DSPs. As will be explained, the number of independent output signals is a function of the number of bits in the multi-bit register. For example, if signal unit 23 includes a 16-bit register, 16 independent output signals may be generated and routed to any 16 different interrupt input terminals of one or more DSPs.

It will be appreciated that the dedicated output terminals of DSPØ are available for other functions in system 20. For example, output 1 and output 2 terminals may be used for purposes other than providing interrupt signaling, as shown in FIG. 2.

FIG. 3 illustrates another embodiment of the invention, generally designated as 30. As shown, system 30 includes signal unit 33 generating output signals for DSPØ (designated as 32). DSPØ may synchronize with DSP1 (designated as 34) by using the output signals generated by signal unit 33 (designated as 33).

As will be explained, the inter-DSP signaling of system 30 is similar to the inter-DSP signaling of system 20, except for address decoding. System 30 does not require address decoding, while system 20 requires decoding. The difference in decoding is due to signal unit 23 (FIG. 2) having  
5 a memory-mapped register (not shown), while signal unit 33 (FIG. 3) has an off-core register (not shown) that is not accessible in the DSP's address space.

A memory-mapped register exists at a particular address in the DSP's address space. The register receives a full address on bus 25, data on  
10 bus 26 and a write/read command on line 27, as shown in FIG. 2. Writing or reading to/from the register in signal unit 23 is similar to writing or reading to/from any other memory location accessible by DSPØ. The logic that performs the memory mapping (shown in FIGS. 4 and 6) decodes the address to determine if the register is being accessed, and the read/write  
15 command determines whether data on the data bus is being loaded to the register or data is being driven onto the data bus from the register.

An off-core register is not accessible in the DSP's address space. Dedicated hardware in the DSP directly accesses this type of register. The register is accessed by using read/write strobes from the hardware and  
20 compiler support to provide instructions to access the hardware. The address and read/write decoding necessary in memory-mapped register operations is unnecessary for off-core register operations. As shown in FIG. 3 (and in greater detail in FIG. 5), data bus 36 and write strobe line 37 are connected to signal unit 33; the address bus is not used.



Referring to FIG. 4, inter-DSP signaling between multiple DSPs will now be explained in greater detail. As shown, bi-directional inter-DSP signaling system 40 includes multiple DSPs; only two (DSPØ and DSPx) are shown, respectively designated as 41 and 46. Signaling unit Ø, generally designated as 42, forms a set of output signals from data bits having been placed on data bus 81 by DSPØ. The formed output signals are placed on dedicated lines 89 and routed to the interrupt terminals of respective DSPs. For example, one interrupt terminal, designated as 87, is shown in DSPx.

Similarly, signaling unit x, generally designated as 47, forms another set of output signals from data bits having been placed on data bus 84 by DSPx. The output signals are placed on dedicated lines 90 and routed to the interrupt terminals of respective DSPs. For example, one interrupt terminal, designated as 88, is shown in DSPØ.

Data bits on data bus 81 are stored in memory-mapped register 44, after decoder 43 determines that the address placed on address bus 82 matches the address of register 44. Decoder 43 is enabled by a write command on line 83 and register 44 is enabled by an output signal from decoder 43. When data is clocked out from the Q output terminal of register 44, the data is detected by edge detector 45. A logic ONE on any data bit from register 44 provides an output signal on a specific line of dedicated lines 89. The output signal may then be provided as an interrupt signal to any processor, for example, an interrupt signal to interrupt terminal 87 of DSPx.



Similarly, decoder 50 enables memory-mapped register 49, after a write command is placed on line 86 and a correct address is placed on address bus 85. Edge detector 48 detects a logic ONE on any data bit being clocked out from register 49 and provides an output signal on dedicated lines 5 90. The output signal is routed to any processor for use as an interrupt signal. For example, the output signal may be routed to interrupt terminal 88 of DSPØ, as shown in FIG. 4.

It will be appreciated that data busses 81 and 84 each transmit parallel data bits, for example 16 parallel data bits on 16 parallel lines, 10 respectively. Similarly, registers 44 and 49 each include multiple flip/flops, for example 16 flip/flops, each flip/flop storing one bit of data. Edge detectors 45 and 48 are each capable of detecting a logic ONE from any Q output terminal of the multiple flip/flops of respective registers 44 and 49. Each edge detector may then provide multiple output signals for use as 15 interrupts. For example, if register 44 includes 16 flip/flops, then 16 independent output signals may be provided to multiple processors for use as interrupts.

Operation of the inter-DSP signaling system will now be explained in greater detail by referring to FIGS. 5-7. FIG. 5 depicts a 20 signaling unit, generally designated as 52. The decoder function includes a set of 16 AND-gates 53. The register includes a first set of 16 flip/flops 54 and the edge detector includes a second set of 16 flip/flops 55 and a set of 16 AND-gates 56.

A write strobe (wr\_sig) is provided to each AND-gate of the 16 AND-gates 53. Each data bit of data bus (15..0) is also provided to one AND-gate of the 16 AND-gates 53. Each AND-gate 53 is enabled, when the write strobe is a logic ONE and a respective data bit is a logic ONE. A logic ONE is clocked into a respective flip/flop 54 of the register by the clock signal. On the next clock, the data passes from flip/flop 54 into flip/flop 55. An interrupt signal is enabled on one of the output lines (int(15..0)) when a respective Q terminal of flip/flop 54 has a logic ONE and a respective QN (Q-not) terminal of flip/flop 55 has a logic ONE.

The operation of signaling unit 52 may be better understood by referring to FIG. 7. As shown, the input signals to system 52, namely the clock, the data on data bus (15..0) and the write strobe (wr\_sig), are illustrated as a function of time, respectively in FIGS. 7(a)-7(c). For example, data bit 0 (LSB) is a logic ONE during the first clock cycle and data bits 0 and 1 are both logic ONE during the third clock cycle, as shown in FIG. 7(b).

The signal provided to the D terminal of each of the first set of 16 flip/flops 54 (the register) is shown in FIG. 7(d). The signal is the same as the signal shown in FIG. 7(b). The output signal from the Q terminal of each of the 16 flip/flops 54 is shown in FIG. 7(e). The output signal is delayed by one clock cycle from the input signal at the D terminals of the register. FIG. 7(f) depicts the output signal from the QN output terminals of the second set of 16 flip/flops 55. The second QN output signal is a logical inverse of the first Q output signal, after it is delayed by one clock cycle.

After logically combining the output signal from the Q output terminals of the register and the output signal from the QN output terminals of the second set of flip/flops 55, AND-gate 56 generates an interrupt signal (int(15..0)), as shown in FIG. 7(g). The first write signal (FIG. 7(c)) sets bit  
5  $\emptyset$ , which causes int(0) to be asserted for one clock cycle, as shown in FIG. 7(h). The second write signal (FIG. 7(c)) sets bits  $\emptyset$  and 1, which causes both int(0) and int(1) to be asserted for one clock cycle, as shown in FIGS. 7(h) and 7(i), respectively.

Register 54, as shown in FIG. 5, is an off-core implementation.  
10 To convert register 54 from an off-core implementation to a memory-mapped implementation, the circuitry shown in FIG. 6 may be incorporated into the inter-DSP signaling system of FIG. 5. The wr\_sig signal of FIG. 5 is replaced by an address bus, a write/read signal and logic circuitry for comparing the address on the address bus to the address of the register.  
15 Circuit 60, which performs the logic, includes comparator 62, constant 61 and AND-gate 63. As shown, when the address on address bus (15..0) matches the address of the register (shown as constant 61) and the write command is set, AND-gate 63 enables the write signal.

The signaling system described herein may be used by any one  
20 DSP to synchronize with any other DSP or multiple DSPs by simply writing a logic one to the appropriate bit at the appropriate address. Any register (memory mapped or off-core) may be used by the DSP. Since existing registers are used, it will be appreciated that modifications are not required to existing DSP circuitry. The described method of signaling may be repeated

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